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SOVIET DEVELOPMENTS IN HIGH TEMPERATURE CERAMICS  
NUMBER 1, JANUARY-DECEMBER 1975

J. Kourilo

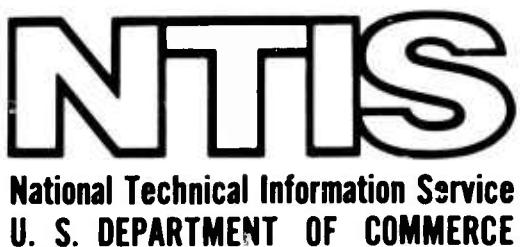
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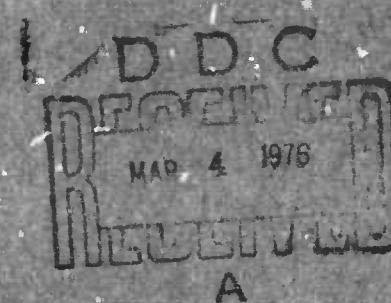
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# SOVIET DEVELOPMENTS IN HIGH TEMPERATURE CERAMICS

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This is a collection of abstracts of recent Soviet-bloc articles on high-temperature ceramic materials. The work is based on a previous published bibliography covering the first half of 1975 ( <u>Soviet Developments in Material Science</u> , No. 1, January - June 1975), together with any similar material that appeared in the last half of 1975. All publications relevant to the subject have been included, with particular emphasis on applications to MHD generators. Entries from the Soviet Reference Journals (RZh) are translated verbatim, otherwise extended abstracts have been made.		

## INTRODUCTION

This is a collection of abstracts of recent Soviet-bloc articles on high-temperature ceramic materials. The work is based on a previous published bibliography covering the first half of 1975 (Soviet Developments in Material Science. No. 1, January - June 1975), together with any similar material that appeared in the last half of 1975. All publications relevant to the subject have been included, with particular emphasis on applications to MHD generators. Entries from the Soviet Reference Journals (RZh) are translated verbatim, otherwise extended abstracts have been made.

For convenience all entries are grouped by principal subject into studies of high-temperature electric insulation materials (Part 1) and high-temperature electrode materials (Part 2). The entries within each part are arranged in alphabetical order by author.

## SUMMARY

The bulk of Soviet effort in development of high-temperature ceramic insulation materials for MHD generators is directed at improving preparation techniques, as well as thermomechanical and electrical characteristics of magnesia and alumina-base ceramics. These materials and combinations of magnesia with zirconia or zirconia and chrome spinel have been tested with some success in insulation of channel walls in pilot MHD plants. A few experimental studies were made on dense zirconia base and refractory aluminum, boron and silicon nitride ceramics for service at 1750 to 2000° C. One study deals with technology of dense beryllia ceramic products. The intended application of the cited materials is generally not specified.

Almost all studies on ceramic electrode materials can be described as relevant to MHD generators. Four types of electrode materials were studied: zirconia stabilized with rare earths, silicon carbide, refractory metal boride- and carbide-based materials, and rare-earth chromites. About half of all studies deal with experimental determination of electrical and some other characteristics of the tested materials. Four studies are devoted to technology of the materials, such as stabilized zirconia, a binary metal carbide composition, and rare-earth chromites. Testing in an MHD channel is described of electrodes made from stabilized zirconia, silicon carbide, zirconium boride and a zirconium boride plus tungsten composition.

This review thus indicates a vigorous ongoing experimental effort by the Soviets in their search for stable high-temperature materials in MHD as well as other demanding applications.

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## 1. Insulation Materials

Akishev A. Kh. and S. M. Zubakov.  
Vysokoplotnyye periklazovyye ogreupory  
(High-density periclase refractories). Institut  
metallurgii i obagashcheniya AN KazSSR.  
Deposit at VINITI no. 2254-74, 14 Aug. 1974,  
7 p. (RZhKh 19M, 1/75, no. 1M73 Dep).  
(Translation)

Sintering is studied of a high-purity magnesia, obtained by thermal activation of magnesium carbonate.

Akishev, A. Kh., S. M. Zubakov and N. V. Kirchanova. Plotnyye periklazovyye izdeliya melkokristallicheskogo stroyeniya iz karbonata magniya s dcbavkoy khromspinelida. (Dense, fine-crystalline periclase products from magnesium carbonate with chromospinelide additive). Institut metallurgii i obogashcheniya AN KazSSR. Deposit at VINITI no. 2255-74, 14 Aug. 1975, 6 p. (RZhKh 19M, 1/75, no. 1M76 Dep.). (Translation)

Sintering of periclase refractories is studied. A mixture of magnesium carbonate with chromospinelide was thermally activated and fired at  $1700^{\circ}$ . The densest products with 1.5 to 3.48% porosity were obtained by thermal activation at  $1100^{\circ}$  of a mixture with 3 to 15% chromospinelide.

Antonov, G. I., V. S. Shapovalov, V. P.  
Nedosvitiy and G. N. Shcherbenko. A body  
for an electrically fused refractory. Authors'  
Certificate no. 423776, published 25 Sept. 1974.  
(RZhKh 19M, 8/75, no. 8M53 P). (Translation)

The body contains (in % by wt.): 30 to 65 alumina, 20 to 50 calcined magnesite, 5 to 20 chromite and 1 to 10 zirconia. The body was prepared and the material was fused and cast by standard procedures. The electrically fused spinel obtained from this refractory has a dense fine-grained structure with 0.8 to 1.7% open porosity and exhibits a high refractoriness ( $2150^{\circ}$ ).

Antonov, G. I., V. S. Shapovalov, V. P.  
Nedosvitiy and G. N. Shcherbenko. A body  
for an electrically fused refractory. Authors'  
Certificate no. 425878, published 7 Oct. 1974.  
(RZhKh 19M, 8/75, no. 8M53 P). (Translation)

The composition of this body is (in % by wt.): 40 to 70 magnesite, 20 to 50 chromite and .05 to 10 Mn, as for example in  $MnSiO_4$ . Standard methods of ceramic processing were used for specimen preparation, material fusion and production. The material thus prepared exhibits a dense, fine-grained structure with 1.5 to 2.3% apparent porosity and an elevated refractoriness ( $2180^{\circ}$ ).

Bron, V. A., V. A. Perepelitsyn, N. A. Mityushov  
and I. A. Stepanova. Effect of a gaseous medium on  
physicochemical conversions in fused periclase under  
heat. IN: Sb. Vliyanie gaz. sredy nakhim. reaktsii  
v proizvodstve silikat. materialov. Vil'nyus, 1974,  
87-88. (RZhKh 19M, 11/75, no. 11M71). (Translation)

It was established experimentally that changes in composition and structure of periclase, from heat-treating of periclase powder in different

gaseous media, result in wide variations in electrophysical characteristics. Impurity content and form in periclase and periclase crystal lattice defects are the main factors which affect electrophysical characteristics, and they depend on the nature of gaseous medium.

Periclase was heat-treated in an oxidizing medium (air), a neutral (helium) or a reducing (dissociated ammonia) medium. Sequential heat treatment in a reducing and then an oxidizing medium, with adjustment for periclase type, is recommended to improve electrophysical characteristics.

Churakova, R. S., and Ye. P. Fedorova.

Electrolytical corundum products obtained by slip casting. Vsesoyuznyy institut nauch-issled. i proekt. rabot ogneupornoy promyshlennosti. Trudy, no. 3(46), 1974, 54-61. (RZhKh 19M, 11/75, no. 11M62). (Translation)

A slip casting technique has been developed for manufacture of electrolytical corundum products. The physical and mechanical characteristics of the material thus obtained are up to  $2000 \text{ kg/cm}^2$  flexure strength temperature cycling to  $1300^\circ$ ,  $4 \times 10^7$  to  $7 \times 10^4 \text{ ohm} \times \text{cm}$  resistivity at  $10^{10} \text{ Hz}$  frequency within a  $600$  to  $1400^\circ$  range, and over  $20 \text{ kv/mm}$  breakdown voltage at  $20^\circ$ . The electrolytical corundum material can be used as high-temperature insulation.

Cwen, A. A high-refractory ceramic for use in the channel of an MHD generator. Szklo i ceram., v. 25, no. 11, 1974, 337-340. (RZhKh 19M, 10/75, no. 10M85). (Translation)

Data are presented on the main characteristics of several refractory materials which are being used in MHD channels as insulators or electrodes. A high-alumina ceramic as well as magnesium and beryllium oxide

ceramics and periclase concrete are in use as insulating materials. Calcium oxide-, ceria- and yttria-stabilized zirconia ceramics are being used as electrode materials. High-temperature electric conductivity of the cited materials is given. Current research in other countries is also reviewed.

Gordova, M. R., I. G. Kuznetsova and D. N. Poluboyarinov. Effect of surface-active additions on dispersion of aluminum nitride powder.

Moskovskiy khimiko-tehnologicheskiy institut imeni D. I. Mendeleyev. Trudy no. 82, 1974, 72-74. (RZhKh 19M, 13/75, no. 13M34). (Translation)

The effect of various surface active substances (type GKZh-94, oleic acid, triethanolamine) on the dispersion of AlN powder was studied to obtain a high-density ceramic. Conditions for obtaining a highly-dispersed AlN in different grinding units are optimized. The effect of dispersion of the initial powder on density of the fired ceramic was studied. An aluminum nitride ceramic with nearly theoretical density (97.5 to 99.5%) was obtained.

Gordova, M. R., S. V. Morozov, A. V. Fedotov, I. G. Kuznetsova and D. N. Poluboyarinov. Interaction of boron nitride and aluminum nitride with high-refractory compounds and refractory metals. Moskovskiy khimiko-tehnologicheskiy institut imeni D. I. Mendeleyev. Trudy, no. 82, 1974, 76-78. (RZhKh 19M, 13/75, no. 13M37). (Translation)

Chemical reactions at 1400 to 1800° C were studied between boron and aluminum nitrides and reactions of these nitrides with Mo, W, Ta and Nb, as well as  $\text{Al}_2\text{O}_3$ ,  $\text{Sc}_2\text{O}_3$ , BeO,  $\text{Y}_2\text{O}_3$ , MgO and  $\text{ZnO}_2$  (sic) high-refractory oxides, and oxygen-free SiC and  $\text{Si}_3\text{N}_4$  compounds. Boron and aluminum nitrides do not interreact up to 1800°, and do not react with  $\text{Sc}_2\text{O}_3$ , BeO,  $\text{Al}_2\text{O}_3$ , SiC, or  $\text{Si}_3\text{N}_4$ . Thus BN and AlN ceramics can be successfully used in various structures at high temperatures in contact with the cited group of materials.

Grebnyuk, A. A., A. G. Karaulov and T. Ye. Sudarkina. Study of thermomechanical characteristics of refractories made from zirconia-base and magnesia-base materials of technical grade or chemically pure. IN: Sb. Proizvodstvo spetsial'nykh ogneuporov, no. 1. Moskva, 1974, 50-66. (RZhKh 19M, 4/75, no. 4M70). (Translation)

Comparative thermomechanical characteristics are cited for zirconia and magnesia, both chemically pure and technical grade. It is shown that creep is smaller and thermal stability is higher for chemically pure than technical grade  $ZrO_2$ . Structural strength of magnesia is even lower than that of technical grade  $ZrO_2$  at 1800 to 2000°. Properties of  $ZrO_2$  and  $MgO$  packings are given.

Gropyanov, V. M., G. V. Drozdetskaya and L. V. Kozlovskiy. Strength characteristics of sintered corundum versus its porosity. Problemy prochnosti, no. 1, 1975, 94-96.

The effect of porosity  $P$  on the mean bending strength  $\bar{\sigma}$  and the measure of dispersion  $S_{\sigma}^2$  is evaluated by statistical treatment of a large number (40 to 140) of corundum specimens. Specimens of  $Al_2O_3$  with 2%  $TiO_2$  and 2%  $MnO_2$  admixtures, sintered to different  $P$  values, were used to measure  $\sigma$  with an automatically loading instrument. The minimum number  $m$  of specimens required to obtain a given measuring accuracy  $\epsilon_{\sigma, m}$  and  $\epsilon_{P, m}$  in a given confidence interval was calculated from the tabulated statistical data. Calculations show that  $m$  increases sharply with increase in porosity  $P$ . An increase in  $S_{\sigma}^2$  owing to an increase in  $\bar{P}$  is attributed mainly to the disordering effect of  $P$ , and much less to  $S_P^2$ . Thus, the effect of  $P$  on accuracy of  $\sigma$  measurement in sintered materials must be taken into account. In the first approximation,  $m$  must be increased twofold for each 5% increase in  $P$  in the 1 to 30% range of  $P$ , in order to measure  $\sigma$  with the same accuracy.

Ignatova, T. S., L. V. Uzberg and V. A.

Perepelitsyn Effect of a ZrO<sub>2</sub> admixture on properties of magnesia products. IN:  
Sb. Proizvodstvo spetsial'nykh ogneuporov,  
no. 1. Moskva, 1974, 74-93. (RZhKh 19M,  
4/75, no. 4M64). (Translation)

Solubility of ZrO<sub>2</sub> in magnesia at 1700 to 2800° was studied. The ZrO<sub>2</sub> solubility was found to be limited, using petrographic analysis. The effect of ZrO<sub>2</sub> admixture on mechanical characteristics of magnesia products depends on the activity of the initial MgO material. Mechanical characteristics of periclase materials with different structures can be improved by ZrO<sub>2</sub> admixtures.

Karaulov, A. G. Lining mixtures based on zirconia with orthophosphoric acid binder.  
Ogneupory, no. 7, 1975, 40-46.

Experimental research data are detailed on the effects of monoclinic ZrO<sub>2</sub> additives, degree of stabilization of the granular component, and orthophosphoric acid content on properties of lining mixtures for various plants with service temperatures to 2000° C. The mixtures with 5 mm maximum grain size, based on ZrO<sub>2</sub> completely stabilized with 5.5 wt% CaO with addition of 30% monoclinic ZrO<sub>2</sub>, or ZrO<sub>2</sub> partly stabilized with 4.5 wt% CaO without any monoclinic ZrO<sub>2</sub> addition, were found to be the most suitable for use in unfired monolithic liners. A constant volume (absence of shrinkage) and a sufficient ultimate compressive strength  $\sigma_c$  over the range of service temperatures were the main criteria for suitability of the mixtures.

The cited most suitable mixtures with 5 wt% phosphoric acid ( $d = 1.72$ ) addition exhibited a 0.5 to 0.7% shrinkage to 1750° C and a  $31 \text{ kg/cm}^2$   $\sigma_c$  at 1750° C, i.e., about the same  $\sigma_c$  as the fired granular refractories. The maximum  $\sigma_c = 491 \text{ kg/cm}^2$  at 1200° C for the optimum mixture is sufficiently high for service in liners. A weakening of an intermediate lining layer at 1600° C does not significantly affect usage in plants at 2000° C or above, since the strength of the working layer at 1750 to 2000° C is sufficient. A restabilization of cubic ZrO<sub>2</sub> occurs at 2000° C after a destabilization attains a peak at 1600° C. Optimum lining mixtures are recommended for plants with a service temperature of 2000° C and above.

Khudyakov, A. V., E. I. Laskina and N. A. Marakuyeva. A procedure for treatment of refractory oxide products and cermets based on refractory oxides. Author's certificate USSR, No. 453385, published 24 January 1975. (RZhKh 19M, 14/75, no. 14M24 P).  
(Translation)

A refractory treatment is described which involves firing at a temperature equal to 0.4 to 0.7 of the melting point of the material. Firing is carried out in vapors of diffusion-accelerating compounds, e.g., boric anhydride, magnesium, or calcium, to obtain a vacuum-tight product. As an example a polycrystalline beryllia product with  $2.8 \text{ g/cm}^3$  density, a  $10 \mu$  grain size, and 6.7% open porosity was prepared by a known procedure, e.g., dry or wet compacting and sintering. The vacuum-leaky product was heat-treated at  $1500^\circ$  for 1 hour in a vacuum furnace in which a boric anhydride, magnesium, or calcium vapor atmosphere is created at a  $10^{-2}$  torr pressure. After such a treatment the product dimensions, density, grain size and total porosity do not change, but open porosity is converted into sealed porosity.

Kozlovskiy, L. V. and I. T. Sintsova.  
Effects of magnesia and yttria on sintering and ceramic properties of corundum ceramics.  
IVUZ Khim, no. 11, 1975, 1825. (Translation)

A  $150^\circ$  decrease in sintering temperature and very high density ( $3.99 \text{ g/cm}^3$ ) specimens were produced by simultaneous admixture of 0.1 to 2 wt%  $\text{MgO}$  and  $\text{Y}_2\text{O}_3$  to a corundum body. Microscopic examination of the body and study of the average grain size versus admixture concentration indicated that the fine-crystalline structure of the  $\text{MgO}$ - and  $\text{Y}_2\text{O}_3$ -containing bodies is apparently the result of a chemical interaction between the oxides and not the effect of each individual oxide.

Mel'nik, M. T., N. N. Shapovalova and A. G. Mossur. Concrete of highest refractoriness.  
Vestnik Khar'kov. politekhnicheskiy institut,  
no. 98, 1974, 51-52. (RZhKh 19M, 6/75, no. 6M85)

Exploratory data are given on preparation of a concrete based on a zirconium-containing cement and exhibiting peak refractoriness. The high-refractory ( $>2000^{\circ}$ ) concrete is recommended as lining material for operation at temperatures over  $2000^{\circ}$ .

Orlova, I. G., L. A. Dergaputskaya and I. S. Kaynarskiy. Corundum ceramics with reduced shrinkage during firing. Ogneupory, no. 6, 1975, 39-44.

Attempts are described at decreasing shrinkage, hence deformation, of slip cast corundum blanks during high-temperature firing. Deformation is particularly important in large size, thin-walled (5 to 7 mm) complex shape products, such as toroidal chambers, oval and rectangular channels or rings with up to 400 mm diam. Apparent density  $\gamma$  of a blank was used as a criterion of shrinkage S.

The experimental data show that  $\gamma$  of the mold-castings from technical grade alumina slurry increases to  $2.86 \text{ g/cm}^3$  and S decreases to 8.5% after firing at  $1750^{\circ}\text{C}$ , i.e., S is 1.5 to 3% lower than after firing at 1550 to  $1700^{\circ}\text{C}$ . Mold-castings with  $2.90$  to  $2.97 \text{ g/cm}^3$   $\gamma$  were obtained from alumina or electrolytic corundum slurries with triethanolamine additive. Attempts at casting dense slurries, casting vibrating or magnetized slurries or suspensions in saturated aluminum salts solutions, or finishing compression of mold-castings, failed to decrease porosity or increase  $\gamma$ .

Apparent porosity and S of the castings were decreased (the latter to 6-7% vs. 12-14% for standard corundum ceramics) by impregnating castings with aluminum-ammonium or -potassium melts and subsequently firing at  $1750^{\circ}\text{C}$ . Deformation during firing of 200 mm diam, rings with 6 mm wall, produced by the described process, decreased from 3.6 to 1.6%. A pore-free corundum ceramic ( $>99.67\%$   $\text{Al}_2\text{O}_3$  and 0.003 to 0.03%  $\text{Na}_2\text{O}$ ) thus produced exhibits a  $3.8 \text{ g/cm}^3$   $\gamma$ , 2600 to  $3280 \text{ kg/cm}^2$  ultimate bending strength, 19.5 to 22.9 kv/mm breakdown voltage, and  $1.6 \times 10^{-4}$  to  $2.2 \times 10^{-4}$  dielectric loss tangent at 1 MHz.

Orlova, I. G., N. V. Gun'ko, A. I. Natsenko and I. S. Kaynarskiy. Phase composition and microstructure of corundum-base ceramics versus their thermal stability. IN: Sb. Proizvodstvo spetsial'nykh ogneuporov, no. 1. Moskva, 1974, 104-128. (RZhKh 19M, 4/75, no. 4M60). (Translation)

The microstructure of corundum and corundum-base ceramics is studied in relation to the ceramic's thermal stability. Comparison of structural characteristics of the studied multiphase ceramics to their thermal stability shows that the structures in which extraneous (noncorundum) phases are both intra- and intercrystalline (along a corundum crystal boundary) display the highest stability (>100 air thermal cycles from 1500°). Such structures are formed by addition of  $ZrSiO_4$ . The specimens in which the second phase is intercrystalline are the least thermally stable (from 45° to zero).

Osipova, I. I. and D. A. Pogorelova.  
Recrystallization of silicon nitride from hot pressing. Por. met., no. 12, 1975, 74-77.

Changes in microstructure and granulometric composition of silicon nitride in the process of hot pressing were studied by optical and electron micrographic techniques. Hot-pressed  $Si_3N_4$  was the subject of the study, because of the high density, strength and thermal stability characteristics of materials based on hot-pressed  $Si_3N_4$ . Micrographs, electron micrographs and particle size distribution histograms of the original  $Si_3N_4$  powder and  $Si_3N_4$  hot-pressed with 5% MgO addition are shown. It was established that in the process of hot pressing part of the needle-shaped prismatic particles are converted, mainly into smaller isometric grains. Granulometric composition of the material, however, is hardly changed. In addition to diminution of original grain only an insignificant localized secondary recrystallization of the finely dispersed original material occurs with an increase in size to 20-30  $\mu$  of the needle-shaped and isometric grains. Compaction of  $Si_3N_4$  is not significantly affected by recrystallization.

Poluboyarinov, D. N., M. R. Gordova, I. G.  
Kuznetsova, I. P. Shalamova and V. A. Silayev.  
Technology and properties of aluminum nitride  
high-density products. Ogneupory, no. 6, 1975,  
44-47.

The possibility of preparing a dense ceramic from AlN powder was explored, since this type of ceramic material appears as one of the most promising to satisfy the requirements of several new engineering fields. Experiments are described to determine the effects of dry and wet grinding with or without surface active agents addition, on the particle size of the AlN powder. The powder with maximum specific surface was obtained after a 2 hour grinding of AlN with 2.5% triethanolamine additive. Density of ceramics made from such powder by compacting and firing at 1900°C in nitrogen approached the theoretical limit. Density of the specimens increased, when the firing temperature was raised from 1600 to 1950°C.

Ceramic blanks produced under the cited optimum conditions exhibited 98.5 to 99.7% relative density, 2000 to 2500 kg/cm<sup>2</sup> ultimate bending strength at 20°C, deformation onset under 2 kg/cm<sup>2</sup> load at >1950°C,  $4.8 \times 10^{-6}$  thermal expansion coefficient in the 100 to 800°C range,  $1.5 \times 10^{-3}$  ohm x cm. resistivity at 1500°C, 8 to 8.6 dielectric constant, and  $5 \times 10^{-4}$  to  $2 \times 10^{-4}$  dielectric loss tangent at 20°C and f =  $10^6$  Hz. Oxidation starts at 1300°C. Weight gain was maximum 0.25% after 5 hr oxidation at 1400°C. AlN products can thus be used as structural materials under sharp temperature gradient conditions at temperatures to 1300°C in oxidizing media, and to 1800°C in an inert atmosphere. Ceramics produced by the described process can be used as high-temperature electric insulators and dielectrics.

Proizvodstvo spetsial'nykh ogneuporov. (Manufacture of special refractories). Tematicheskiy otrslevoy sbornik no. 1. Moskva, Metallurgiya, 1974, 215 p. (RZhKh 19M, 3/75, no. 3M42 K). (Translation)

This is a collection of articles dealing with the physics, chemistry, technology and uses of aluminosilicate, periclase, periclase-spinelide and light-weight refractories. Thermal, thermomechanical and other characteristics are examined. Problems of analysis of raw materials and refractories are discussed. Studies on processing technology of boron

nitride products and synthesis of nickel-chromium spinels are included. The problems are also treated of mechanical processing of refractories, welding of ceramics, preparation of raw materials, standardization of scientific and technical terminology, and application of mathematical statistics methods to economic evaluation of refractory products, with respect to quality and cost.

Rutman, D. S., N. M. Perminina, L. S.

Zholobova, T. N. Kudryavtseva, A. V.

Mytnikov and N. M. Andreyev. Preparation of alumina with activated sinterability and corundum ceramics. Ogneupory, no. 9, 1975, 45-52.

Activated heat-treatment of  $\text{Al(OH)}_3$  in the presence of mineralizing admixtures was studied in an attempt to simplify the process of manufacturing densely sintered corundum ceramics. The mineralizing admixtures, such as  $\text{AlF}_3$ ,  $\text{MgF}_2$ ,  $\text{NH}_4\text{F}$ ,  $\text{H}_3\text{BO}_4$  and  $\text{NH}_4\text{Cl}$ , were used to convert  $\gamma\text{-Al}_2\text{O}_3$  to  $\alpha\text{-Al}_2\text{O}_3$  of increased sinterability. A 100% conversion within a narrow range of firing temperatures (1000 to  $1060^\circ\text{C}$ ) was achieved with a minimum 1% addition of  $\text{AlF}_3$ ,  $\text{NH}_4\text{F}$  or  $\text{MgF}_2$  at  $70^\circ\text{C/hr}$  heating rate. The same result was obtained at even lower firing temperature, when the mineralizing addition was in the form of a solution rather than powder.

Experiments carried out at the Eastern Institute of Refractories with corundum ceramics based on the factory-produced test run of  $\alpha$ -alumina, and on the laboratory-made  $\alpha$ -alumina specimens, have shown that densely-sintered ceramics can be produced by a simplified process using  $\alpha\text{-Al}_2\text{O}_3$  crystallized at a lower temperature than in the conventional process. The apparent density of the ceramic specimens thus prepared was 3.80 to 3.90  $\text{g/cm}^3$ . Substitution of alumina-firing in fluidized-bed ovens for rotating ovens becomes possible due to decrease firing temperature range. The simplified process has been used to produce dense corundum ceramics at the Podolskiy Plant for Refractory Products.

Samsonov, G. V., L. I. Prikhod'ko and N. I. Borshch. Obtaining nitride materials through nitriding of aluminum dodecaboride blanks.

NM, no. 4, 1975, 657-660.

An attempt is described at producing a BN- and AlN-based material which would combine the high strength of AlN with the high refractoriness and electrical insulation characteristic of BN. Such a material has been obtained by nitriding with pure nitrogen at 1890 to 2000° C a finely ground and compacted aluminum dodecaboride ( $AlB_{12}$ ) powder. The experimental kinetics data show that the nitriding rate is highest at 2000° C and the reaction is completed in one hour. Nitriding at 1800° C is preferable (although slower) because of the lower porosity (20 to 22%) of the product. Shrinkage of the specimens was observed during sintering for over 1 hr at 2000° C.

Specimens sintered for 4 hr at 1800° C exhibited a 2 to 3 kg/mm<sup>2</sup> bending strength vs. 0.2 to 0.5 kg/mm<sup>2</sup> for BN, and much higher electrical characteristics than either BN or AlN. The increased resistivity of the material in comparison with pure BN is attributed to formation of an (Al, B)N solid solution because of the distorted AlN crystal lattice in the nitrided product.

Samsonov, G. V., V. K. Kazakov, P. S. Kislyy and G. V. Trunov. A refractory composition. Author's certificate USSR, no. 435215, published 13 November 1974. (RZhKh 19M, 18/75, no. 18M65 P). (Translation)

A refractory composition is introduced, which may be used, for example, for joining electrical insulation blanks. The composition is based on silicon nitride and contains (in % by wt): 3 to 15 MgO and 0.5 to 4.5  $SiO_2$ . Characteristics of the composition are:  $10^{11}$  ohm x cm resistivity, >30 11,500°-air thermal cycles, and 1700 to 1750° service temperature.

Samsonov, G. V., V. K. Kazakov, P. S.  
Kislyy and S. S. Gorodetskiy. A refractory material. Authors' certificate USSR, no. 422705, published 19 September 1974. (RZhKh 19M, 13/75, no. 13M64 P). (Translation)

The cited silicon nitride-base material contains (in % by wt): 4.5 to 15 MgO and 4.5 to 9.5 mullite whiskers. The material is prepared by mixing silicon nitride and MgO powders with mullite whiskers in the required ratio. Next a plasticizer is added, and the mixture thus obtained is compacted and sintered for 2 to 3 hours at 1550 to 1700° in a tubular graphite-resistance oven in an N<sub>2</sub> atmosphere. Measured characteristics of the material are: 47.2 kg/mm<sup>2</sup> compressive σ, 25-1500° - water thermal cycles and 4 × 10<sup>12</sup> ohm × cm. bulk resistivity.

Sartbayev, M. K., S. M. Zubakov, T. A. Lyubimov and V. O. German. Issledovaniye periklazotsirkonokhromoshpinelidnykh ogneuporov zernistogo stroyeniya (A study of periclase-zirconia-chromospinelide granular refractories). Deposit at VINITI no. 1148-75 Dep., 23 April, 1975, 13 p. (RZhElektrotekhn. 21F 9/75, no. 9F7 DEP). (Translation)

Synthesis is reported of the cited refractories, exhibiting a low (3.1%) open porosity, a high (2008 kg/cm<sup>2</sup>) ultimate compressive strength and an enhanced heat resistance (averaging 4 and >50 heating-water cooling and heating-air cooling cycles, respectively). These high quality indices are ascribed to the specific structure plus a low silicate content. The referenced refractories can survive for 20 minutes in an MHD channel module at ≈2100° C surface temperature. Saturation of the refractories with potassium compounds (0.3 to 0.58%), variations in open porosity and apparent density during testing were insignificant.

Sartbayev, M. K., S. M. Zubakov, T. A.  
Lyubimov and V. O. German. Issledovaniye  
periklazotsirkoniyevykh ogneuporov zernistogo  
stroyeniya v model'nom kanale M.GD ustanovki  
(A study of periclase-zirconia refractories in a  
MHD channel module). Deposit at VINITI no.  
1147-75 Dep, 23 April 1975, 10 p. (RZhElektrotekhn  
21F, 9/75, no. 9F8 DEP). (Translation)

The cited periclase zirconia test refractories exhibited a low (3.2%) open porosity, a high ( $1602 \text{ kg/cm}^2$ ) ultimate compressive strength, and an enhanced heat resistance (averaging 5 and  $>50$   $1300^\circ \text{ C}$  to water and  $1300^\circ \text{ C}$  to air thermal cycles, respectively). These high processing characteristics are due to the specific structure and a very low (<0.3%) silicate content. In a 20 minute test in an MHD channel module at  $\sim 2100^\circ \text{ C}$  the high-density type refractories exhibited a high degree of stability. Saturation of the products with potassium compounds (0.35 to 0.5%), variations in open porosity and apparent density in service in a channel model with an admixture, were found to be insignificant.

Sazonova, M. V., I. B. Pan'kovskaya, and A. A.  
Appen. Dense dielectric coatings for porous  
magnesia ceramics. ZhPKh, no. 4, 1975, 822-826.

Attempts are described at depositing dense high-dielectric ceramic coatings on high-temperature porous magnesia ceramics designed at the Academy's Institute of High Temperatures, for electrical insulation of MHD channels. Alumina, magnesia, and alumina-magnesia spinel were tested as coating materials with inorganic and organic admixtures. The attempted deposition techniques included slurry deposition of all three base materials with subsequent firing in an oven at  $1000^\circ \text{ C}$  followed by flame fusion; plasma dusting of the powdered ceramic materials, spinel slurry deposition and subsequent fusion by a plasma jet traveling along the coated surface at some distance; and deposition of MgO with organo silicon lacquers slurry, followed

by oven firing at temperatures to 1,700°.

The latter technique produced MgO coatings with 2 to 5% porosity after firing at 1,700° and  $10^3$  to  $10^4$  ohm x cm resistivity at 1400° C. The most dense spinel coatings on crackfree magnesia ceramic were obtained by heating the deposited slurry with a plasma jet traveling along the coated surface.

Sheyndlin, A. Ye., D. K. Burenkov, V. I.  
Zalkind, V. V. Kirillov, B. I. Rastegayev,  
G. L. Uspenskaya and B. Ya. Shumyatskiy.  
Study of the insulating wall of an MHD channel in  
a continuous-duty generator. TVT, no. 1, 1975,  
151-156.

Results are discussed of continuous (to 300 hr) testing of insulating module walls of different structures in an MHD channel. Testing was carried out in a U-02 pilot model power plant at the Institute of High Temperatures. Natural gas with aqueous potash solution additive and oxygen-enriched air at 1500° C maximum were used as the fuel and oxidizer, respectively. Metallic (Cu, Al, 1 Kh 18N10T steel) wall structures with air or joined intermodular gaps were tested. The gaps were joined with type VGB or AFB high-alumina refractory concrete or micaceous type ("sludenit") bonding material cemented with a heat-resistant compound. The VGB and AFB concretes contain white electrolytic corundum filler and high-alumina cement and aluminum phosphate binders, respectively. Defects of the cited intermodular insulators are shown.

The first test results indicated that, regardless of intermodular gap configuration, hermetization of the internal structural cavity is necessary. The authors conclude that all metallic wall parts, except the fired module surface, have to be coated with a continuous insulating teflon film. Gaps in the cold area have to be sealed with poly(organosiloxane) compound. Intermodular gaps have to be filled flush with the wall with dense cast alumina-base insulating material, platelike in shape and sealed with a high-temperature cement.

With such an intermodular gap structure, the assembly insulation withstood without damage a half-hour of intermodular arcing at 50 to 70 amp. During a 300 hr run the module-supporting beam contact resistance R for this structure was stable at 1.5 to 2 kohm level, as against 0.2 to 0.3 kohm for an unsealed structure. After the run the module-beam insulation withstood a 3 kv potential difference without breakdown.

The guidelines for building modular walls of a continuous duty MHD channel with a sufficient electrical strength are formulated. The optimum wall temperature with respect to intermodular insulation is in the 600 to 800° K range. Dense ceramic is the preferred intermodular material as regards leakage current and arcing resistance, according to this study.

Terekhovskiy, B. I., S. G. Tresvyatskiy, I. D.

Barabanova, N. V. Lesovoy and I. V. Kholodenko.

Test data on the ceramic lining of a pilot MHD generator.

IN: Sb. Voprosy MGD preobrazov. energii. Kiyev.

Nauk. dumka, no. 1, 1974, 57-63. (RZh Elektrotekh,  
21F, 2/75, no. 2F12). (Translation)

Efficiency of a channel heat shield with corundum composites or granular and fused periclase refractories was studied in an MHD pilot plant. Thermal and erosion resistance of the cited materials was investigated in a plasma flow. Data analysis revealed the absence of any erosion of corundum refractory or granular or fused periclase materials at temperatures to 1700, 2300 and 2630° C, respectively.

Terekhovskiy, B. I., S. G. Tresvyatskiy,  
I. D. Barabanova, V. I. Terekhovskiy and G. B.  
Dobrovolskiy. A refractory binder for linings  
of a high-temperature unit. Authors certificate  
USSR, no. 442173, published 15 December 1974.  
(RZhKh 19M, 18/75, no. 18M79 P). (Translation)

The cited refractory binder is composed of (in % by wt)  
30 to 58 magnesia, 20 to 40 periclase, 20 to 30 waterglass and 1.5 to 2.5  
thermite additive. The thermite additive contains (in wt%): 42 chromium oxide,  
36 iron oxide, 16 aluminum and 6 manganese oxide. The refractory binder  
solidifies at 20° and exhibits high refractoriness and binding power in contact  
with metals and ceramics at high temperatures.

Zalivovskiy, Ye. V., B. S. Bobrov, A. A.  
Kondrashenkov and G. I. Zaldat. A mixture  
of raw materials for high-refractory concrete.  
Authors certificate USSR, no. 435203, published  
13 November 1974. (RZhKh 19M, 18/75, no.  
18M254 P). (Translation)

A proposed concrete mixture is composed of a high-alumina  
cement and a filler. Siliconized graphite is used as a filler to increase thermal  
stability. The components are mixed in the ratio (in wt %) of 5 to 25 high-  
alumina cement to 75-95 siliconized graphite.

Zholudov, Ya. S., B. I. Terekhovskiy, A. A.  
Miroshnichenko and G. F. Gornostayev.  
Development and study of a composite insulating  
wall for an MHD channel. IN: St. Teplotekhn.  
problemy pryamogo preobrazov. energii. Kiyev,  
Naukova dumka, no. 5, 1974, 71-78. (RZh  
Elektrotekh. 21F, 1/75, no. 1F52). (Translation)

Data are given on development and testing of a reinforced insulating wall structure in an MHD pilot plant of the Ukrainian Academy and Ukrainian Minenergo. A  $120 \times 200 \text{ mm}^2$  wall lined with  $14 \times 12 \text{ mm}^2$   $\text{MgO}$ -based ceramic modules and reinforced with dovetail type ribs, 8 to 9 mm high and 1.8 mm thick, was tested. A 30 min. test under very stiff conditions at  $\sim 2700^\circ \text{ K}$  plasma temperature and 600 to 700 m/sec flow rate, proved satisfactory. After testing, the ceramic surface was found fused locally at the leading edge to a 2 to 3 mm depth. Hairline cracks appeared at the intermodular boundaries, and the external layer became darker. In comparison, mosaic plates made of different materials broke down completely toward the end of a test.

Zubakov, S. M. and A. Kh. Akishev. Plotnyye periklazovyye ogneupory povyshennoy termicheskoy stoykosti. (Dense periclase refractory with improved thermal stability). Institut metallurgii i obogashcheniya AN KazSSR. Deposit at VINITI no. 2253-74, 14 Aug. 1974, 10 p. (RZhKh 19M, 1/75, no. 1M72 Dep.). (Translation)

Methods of calculating and selecting grain size distribution in a charge are introduced. With the data thus obtained, thermally stable dense periclase refractories have been produced for use in an MHD channel.

## 2. Electrode Materials

German, V. O., Yu. P. Kukota and B. V. Parfenov. Testing of porous cermet electrodes protected by injection of nitrogen with a potassium additive. IN: Sb. Teplotekhn. problemy pryamogo preobrazov. energii. Kiyev. Nauk. dumka, no. 5, 1974, 62-65. (RZhElektrotekh, 21F, 1/75, no. 1F56). (Translation)

Tests of  $ZrB_2$  porous electrodes with  $N_2$  injection indicates that  $N_2$  can be substituted for more expensive argon. Protection by  $N_2$  injection with potassium additive is not less efficient with respect to erosion than protection by argon. The required current density ( $10 \text{ a/cm}^2$ ) can be obtained at a relatively low cathode temperature in the  $1200$  to  $1600^\circ \text{C}$  range.

Gnesin, G. G. and G. S. Oleynik. Thermo-dynamic analysis of silicon carbide interaction with combustion products of organic fuels. IN: Sb. Voprosy MGD preobrazov. energii. Kiyev, Nauk. dumka, no. 1, 1974, 94-101. (RZh Elektrotekh, 21F, 2/75, no. 2F16). (Translation)

Isobaric-isothermic potentials are calculated by approximation for the silicon carbide and silicon reactions with  $\text{CO}_2$ ,  $\text{H}_2\text{O}$  and  $\text{O}_2$  at temperatures in the  $2000$  to  $2900^\circ \text{K}$  range. The gases are the [normal] components of a low-temperature plasma in an open cycle MHD power plant. In such gaseous media, the upper limit of operating temperature may not exceed  $2000^\circ \text{K}$ .

Gnesin, G. G., G. S. Oleynik and N. V. Lesovoy. Service test data on polycrystalline silicon carbide electrodes in the channel of an MHD generator. IN: Sb. Voprosy MGD preobrazov. energii. Kiyev. Nauk. dumka, no. 1, 1974, 101-107. (RZhElektrotekh, 21F, 2/75, no. 2F17). (Translation)

Operating characteristics of polycrystalline silicon carbide electrodes in an open-cycle MHD power plant are given. It was determined that the maximum service temperature of such electrodes should not exceed 1600° C.

Gnesin, G. G., L. A. Shipilova and G. S. Oleynik. Electric conductivity of polycrystalline silicon carbide. IN: Sb. Voprosy MGD preobrazov. energii. Kiyev. Nauk. dumka, no. 1, 1974, 84-94. (RZh Elektrotekh, 21F, 2/75, no. 2F15). (Translation)

Electrical conductivity of seven polycrystalline silicon carbide-based materials was studied. The materials differed with respect to the SiC crystal size and phase composition. Electrical conductivity of polycrystalline SiC was found to increase insignificantly with growth of the original SiC grain. An increased in noncombined Si content caused a significant increase in electrical conductivity of the material. Depending on phase composition, conductivity can be varied within a wide range.

Gokhshteyn, Ya. P. and A. A. Safonov.

Critical current density at ceramic electrodes  
based on zirconia and rare earths. Sb.

Magnitogidrodinam. ustanovki. Moskva, 1975,  
110-122. (RZhElektrotekhn. 21F, 11/75, no.  
11F25). (Translation)

The existence of a definite critical current level above which a specimen breaks down was established during operation of electrodes made of yttria-stabilized zirconium dioxide. This current level coincides with the limiting current on the volt-ampere characteristic. This finding can be applied to selection of safe current and control of the electrode state in service. At  $1673^{\circ}$  K, the average critical current density for a small specimen is 0.8 to 0.9 a/cm<sup>2</sup> under relatively favorable conditions. Such conditions are: a free access of oxygen to the entire specimen surface, a short (1 to 3 mm) embedded cathode length, a significant (25%) porosity and the absence of thermal shock. Critical current density was studied as a function of temperature, specimen size and current lead-out.

Gokhshteyn, Ya. P. and A. A. Safonov.

Critical current density at ceramic electrodes  
based on zirconia and rare-earths. Sb. Mag-  
nitogidrodinovm. ustanovki. Moskva, 1975,  
110-122. (RZhKh 19L, 23/75, no. 23L257).  
(Translation)

Variations of electrical and physical characteristics of  $ZrO_2$ - $Pr_6O_{11}$  base ceramics of different compositions over a prolonged period under direct current (at 2 a/cm<sup>2</sup>) are analyzed. The research data are discussed on the current-carrying capacity without breakdown of the compositions, and on the optimum composition of electrode material for an MHD converter. The specimens of 38  $ZrO_2$ -62 $Pr_6O_{11}$  and 32  $ZrO_2$ -68 $Pr_6O_{11}$  ceramics displayed a maximum (97%) electronic conductivity in air. These specimens substained 3 a/cm<sup>2</sup> current densities without damage over a prolonged period.

Karaulov, A. G. and I. N. Rudyak. Sintering of zirconia with yttria. Ogneupory, no. 2, 1975, 54-58.

Experimental sintering is described of technical grade (97.8%) pure (99.1%) and high purity (99.95%)  $ZrO_2$  stabilized with 4 to 15 mol %  $Y_2O_3$ . A finely-ground mixture of starting materials was compacted into cylindrical specimens which were sintered at 500 to  $1900^\circ C$  for 1 to 6 hr. Sintering kinetics data show that an intensive sintering of the technical grade stabilized  $ZrO_2$  specimens starts at above  $1100^\circ C$ . A rapid increase in shrinkage  $\Delta\ell/\ell$  and density, ultimate compression strength  $\sigma_c$  and a decrease in porosity were observed in the  $1100$  to  $1500^\circ C$  range. At sintering temperatures above  $1500^\circ C$   $\Delta\ell/\ell$  and density increase are decelerated,  $\sigma_c$  decreases from a maximum  $3000 \text{ kg/cm}^2$  at  $1500^\circ C$  for a specimen with 4%  $Y_2O_3$ . Open porosity keeps decreasing to  $1750^\circ C$ . Porosity increases, density and  $\sigma_c$  of the specimens decrease with an increase in  $Y_2O_3$  content to 15%.

In the  $1200$  to  $1500^\circ C$  range,  $\Delta\ell/\ell$  varies as  $\tau^{1/2}$  and  $\tau^{1/3}$  for 4 to 8% and 10 to 15%  $Y_2O_3$  content range, respectively. In the  $1500$  to  $1750^\circ C$  range,  $\Delta\ell/\ell$  of all specimens varies as  $\tau^{1/3}$ . Open porosity varies from 6 to 15% and 27 to 31% for the specimens sintered at above  $1500^\circ C$  with 4 to 8% and 10 to 15%  $Y_2O_3$ , respectively. The high open porosity of the materials sintered above  $1500^\circ C$ , particularly those with increased  $Y_2O_3$  content, coupled with a fast crystal growth at that temperature, makes it impossible to obtain a dense sintered material by the cited technique. Sintering of purer  $ZrO_2$  with  $Y_2O_3$  is difficult. A dense material, e.g. with 3 to 6% porosity, can be obtained by fusion or hot pressing, or by a two-step firing with fine grinding between the steps.

Kharitonov, F. Ya., Yu. G. Yesikov, A. I.  
Lebedev, M. Ye. Surkov and Yu. N. Khudov.  
Electrode material for an MHD generator, based on neodymium and dysprosium oxide-stabilized zirconia. TVT, no. 1, 1975, 230-232.

Comparative measurements are described of the high-temperature bulk electrical resistivity  $\rho_v$  of  $ZrO_2-Nd_2O_3$ ,  $ZrO_2-Dy_2O_3$  and siliconized graphite disk-shaped specimens, and high-temperature compatibility of these electrode materials with a microlite dielectric. The practical importance of the

measurements is stressed with respect to utilization of stabilized  $ZrO_2$  as electrode material in MHD generators in contact with a dielectric.

A complete stabilization of  $ZrO_2$  with 10 mol. %  $Nd_2O_3$  or  $Dy_2O_3$  additions was shown by x-ray diffraction and dilatometric analyses, and was confirmed by linearity of the experimental  $\log \rho_v$  versus  $1/T$  plots within 400 to  $1400^\circ C$  range of  $T$ . Practically, there is no difference in  $\rho_v$  between  $ZrO_2-Nd_2O_3$  and  $ZrO_2-Dy_2O_3$  compositions. At  $1400^\circ C$ ,  $\rho_v$  of the stabilized  $ZrO_2$  becomes equal to that of siliconized graphite. The compatibility study indicated that  $\rho_v$  of the stabilized  $ZrO_2$  system remains constant over a 10 hr period under a 200 v applied d.c. voltage at  $1300^\circ C$ . In contrast,  $\rho_v$  and surface  $\rho$  of microlite in the siliconized graphite-microlite-siliconized graphite system decreased significantly under the same conditions. Thus, stabilized  $ZrO_2$  is fully compatible with microlite, a finely crystalline corundum material.

Klyucharov, Ya. V., V. I. Strakhov and G. G. Sergeyev. A charge for refractories. Author's certificate USSR, no. 414234, published 28 May 1974 (RZhKh 19M, 13/75, no. 13M59 P).

Composition of the cited refractory charge is (in mol. %): 80 to 87  $ZrO_2$ , 10 to 12.5  $Nd_2O_3$  and 0.5 to 10  $Al_2O_3$ . The material is synthesized by stabilizing  $ZrO_2$  with 12 mol. %  $Nd_2O_3$  addition at 1600 to  $1700^\circ$  and mixing the  $ZrO_2-Nd_2O_3$  cubic solid solution powder thus obtained with finely dispersed  $Al_2O_3$  (with  $\geq 70\%$  grains smaller than  $3\mu$ ). The mixture is moistened with a polyvinyl alcohol solution, and the body with 7 to 8% moisture is compacted under 500 to 1000  $kg/cm^2$  pressure. The specimens are fired at  $1750^\circ$ . At high temperatures the  $ZrO_2-Nd_2O_3$  cubic solid solution is partly decomposed owing to  $Nd_2O_3$  reaction with  $Al_2O_3$  to form  $NdAlO_3$  with a high melting point. Mechanical characteristics of the refractories produced from the proposed body are cited.

Kunitskiy, Yu. A. Physical properties of some binary boride systems. IN: Sb. Voprosy MGD preobrazov. energii. Kiyev. Nauk. dumka, no. 1, 1974, 108-112. (RZh Elektrotekh, 21F, 2/75, no. 2F18). (Translation)

Work function versus temperature variation in the 1300 to 2200° K interval was studied in  $TiB_2$ - $ZrB_2$ ,  $TiB_2$ - $NbB_2$ , and  $TiB_2$ - $Mo_2B_5$  binary systems. Also microhardness, thermal expansion coefficient, electrical resistivity and Hall constant of these systems were measured. Presumably, these alloys may be used as high-temperature cathode materials.

Ogorodnikov, V. V. and N. N. Sverdlik.  
Experimental study of densification and homogenization of dispersed mixtures in the TiC-ZrC pseudobinary system during sintering and hot forming. Vysokotemperaturnyye karbidy (High-temperature carbides). Kiyev. Izd-vo Naukova dumka, 1975, 112-118.

In a search for alloys with enhanced mechanical and thermo-mechanical characteristics, hot-pressed or sintered TiC-ZrC alloys with the component ratios varied over the entire range were studied. Densification and homogenization of the alloys were evaluated from micrographic x-ray diffraction, x-ray spectroscopic and electrical conductivity data. Relative density  $\nu\%$  of specimens hot-pressed at 2300° C increased with increase in the second carbide content, and attained the maximum 100% in compositions with 30 to 65 mol. % ZrC. The equimolar alloy became completely homogeneous after 40 min. compression at 2300° C.

In contrast, the equimolar specimens sintered at 2300° C exhibited only an 81.4%  $\nu$  after 320 min sintering, and became homogeneous after a much longer heating than the hot-pressed specimens. Their porosity was higher than that of pure ZrC or TiC. Decomposition of solid solutions with formation of an eutectoid was observed in specimens sintered for less than 40 min. The difference in densification of the hot-pressed and sintered alloys was interpreted in terms of different mechanisms of heterodiffusion.

Oleynik, G. S. Activity mechanism of a silicon carbide polycrystalline electrode in the channel of an open-cycle MHD generator. IN: Sb. Teplotechn. problemy pryamogo preobrazov energii. Kiyev. Nauk. dumka, no. 5, 1974, 66-70. (RZhElektrotekh, ZIF, 1/75, no. 1F55). (Translation)

A model of silicon carbide electrode performance in an open-cycle MHD channel is introduced. Emission current components and mechanical erosion of the electrode are studied as functions of the active surface temperature, alkali additive and water vapor concentrations in the plasma flow, service time, and concentrations of basic and acidic oxide spots on the surface.

Oleynik, G. S. and L. A. Shipilova. Effect of sintering conditions on microstructure and electrical characteristics of self-binding silicon carbide. Por. metal. no. 9, 1975, 30-34.

Microstructure and electrical properties of SiC blanks are examined as a function of their density, particle size and ratio of the initial components in the charge, the presence of alloyed admixtures, and sintering temperature. After a heat-treatment at 2100 to 2300° C, the fine-grained SiC products display a pore-free surface layer and a porous interior only when silicon powder is added to the porous blank before sintering. The bulk porosity and the depth of the pore-free layer vary in the 10 to 60% and 200 to 500  $\mu$  ranges, respectively, depending on density of the raw blanks.

Micrographic data show that a high or a low porosity of the bulk product is due to SiC recrystallization from liquid silicon or from the free silicon vapor phase, respectively. Heat-treatment of fine-grained SiC products at 2400 to 2500° C produces a porous surface layer on a practically pore-free body. The porous layer structure is formed on account of SiC recrystallization from liquid silicon.

Different microstructures were observed in fine-grain SiC heat-treated at 1500 to 1700° C in an N<sub>2</sub> stream or in both fine- and coarse-grained materials heat-treated at 2200 to 2300° C in the presence of B or B plus Al vapors. Alloying with N<sub>2</sub> at 2000° C caused an increase in resistivity σ and absolute value of thermal e.m.f. (α) measured in the 300 to 1300° K range, while alloying the sintered material with B at 2200° C lowered both σ and α by an order of magnitude in comparison with the initial material.

Ordan'yan, S. S., and V. I. Unrod. Interaction in the ZrC-ZrB<sub>2</sub> system. Por. metal, no. 5, 1975, 61-64.

An experimental study of a ZrC-ZrB<sub>2</sub> system was carried out to plot the phase diagram for use in development of high-temperature composite materials. The specimens containing ZrC and ZrB<sub>2</sub> in varied ratios and heat-treated at a temperature above 2300° C were analyzed by micrographic x-ray diffraction and chemical techniques. Melting point of the specimens and microhardness of the predominant phase were measured.

The tabulated data show that mutual solubility of the components is practically nonexistent below 2100° C, and not over 2% by mass of ZrB<sub>2</sub> is dissolved at 2650° C. The plotted phase diagram is a eutectic type with eutectic composed of 57% ZrB<sub>2</sub> and 43 mol % ZrC. Eutectic transformation occurs at 2660±40° C.

Podchernyayeva, I. A., V. S. Fomenko, L. N. Okhremchuk, N. I. Siman and Yu. A. Kunitskiy. Properties of electrode materials based on refractory compounds. IN: Sb. Stroyeniye, svoystva i primeneniye metallidov. Moskva, Nauka, 1974, 201-205. (RZhElektrotekh, 21F, 1/75, no. 1F53). (Translation)

Characteristics of the work function of homogeneous or multi-phase carbides and borides are conditioned on the degree of electron trapping by stable bond configurations. Titanium and zirconium carbides cemented with a d-configuration metal were studied to increase thermal stability of the carbide

cathodes. In comparison with the individual carbides, heat-resistance of the cermets is increased and work function is decreased simultaneously. In principle it is hence possible to develop efficient cathode materials based on refractory compounds and exhibiting satisfactory thermionic emission characteristics simultaneously with enhanced thermal stability.

Poltavtseva, I. S., Yu. P. Kukota, F. I.  
Zakharov and G. V. Trunov. Porous cermet  
materials for electrodes with enhanced gas  
permeability. IN: Sb. Teplotekhn. problemy  
pryamogo preobrazov. energii. Kiyev. Naukova  
dumka, no. 5, 1974, 57-62. (RZhElektrotekh,  
21F, 1/75, no. 1F54). (Translation)

Spherical particles of refractory compounds for use in porous electrodes of an MHD plant were prepared by slurry spraying. Porous multilayered electrodes were made of  $ZrB_2$  and W. Hydrolytic and mechanical strength characteristics of the electrodes were studied.

The geometry of an electrode protected by argon injection and K vapors after a 90 min run in an MHD channel differed from the original by 0.1 mm, i. e., erosion was practically nonexistent. The active surface of an electrode was coated with a  $100 \mu$  oxide film which, according to the x-ray diffraction data, contained Zr, Al and Mg oxides. The presence of the film hardly affected total conductivity of the electrode, while protecting it from further oxidation. Structural analysis indicated a total absence of electrode interaction with potassium vapor at temperatures to  $1600^\circ C$ .

Shipilova, L. A. and G. S. Oleynik. Effect of heat treatment on electrical characteristics of a material based on silicon carbide. Por. Metal., no. 10, 1975, 76-80.

Comparative experimental electrical conductivity  $\sigma$  and thermal e.m.f.  $\alpha$  data are given for monolithic polycrystalline SiC obtained by reactive sintering, and porous polycrystalline SiC materials obtained by recrystallization sintering of the monolithic self-binding material at 2100 to 2450° C in an argon atmosphere. The experiments were designed to determine the maximum temperature of additional heat treatment required to obtain a material with a minimum free silicon content for use in high-temperature heater elements.

In the 300 to 1300° K range a decrease in  $\sigma$  and a rise of  $\alpha$  were observed with an increase in annealing temperature or an increase in isothermal anneal time from 1 to 6 hours. The decrease in high-temperature  $\sigma$  was insignificant, and was due to porosity formed by vaporization of free silicon and to a decrease in the content of electrically active admixtures. Self-binding polycrystalline SiC obtained by reactive sintering and subsequent annealing at 2200 to 2450° C maximum is hence judged suitable for high-temperature heater elements.

Shvayko-Shvaykovskiy, V. Ye., E. K. Keler, A. I. Leonov, and V. P. Popov. Preparation of solid solutions with electron conductivity on a zirconium dioxide base. DAN SSSR, v. 222, no. 6, 1975, 1350-1352.

Development of a  $ZrO_2$ -base electrode material with electronic conductivity for use in an open-cycle MHD power plant was undertaken because of the known tendency of stabilized  $ZrO_2$  to revert to ionic conductivity under operating conditions in an MHD channel. Compositions of  $ZrO_2-Y_2O_3-Me_xO_y$  type, where Me = Ti, Nd, or Ce, were selected for study as the most promising with respect to a theoretically sufficient number of electron carriers on account of change of the admixture valence. The experimental study indicated that  $ZrO_2-Y_2O_3-CeO_2$  solid solutions have the most interesting electrical properties.

The tabulated data on conductivity  $\sigma$  and electronic conductivity component  $t_e$  % at 1300 to 1700° K show that a composition with 2%  $\text{Y}_2\text{O}_3$  and 8 to 10%  $\text{CeO}_2$  is the optimum with  $\sigma = .14 (\text{ohm} \times \text{cm})^{-1}$  and  $t_e = 42\%$  at 1700° K. Parallel measurements of  $\sigma$  and weight loss of the optimum composition indicated that transition from ionic to electronic conductivity occurs at 1400° K. A sharp discontinuity at 1400° K in weight loss versus T dependence was interpreted as the effect of  $\text{Ce}^{+4}$  to  $\text{Ce}^{+3}$  transition.

The observed effect of oxygen partial pressure  $P_{\text{O}_2}$  on  $\sigma_1$  and the  $\text{Ce}^{+4}$  to  $\text{Ce}^{+3}$  transition confirmed that  $\sigma$  becomes electronic as the result of Ce valence change. Hence the onset of electronic  $\sigma$  type can be predicted, if the  $P_{\text{O}_2}$  and T° of electrode operation are known.

Sozanski, A. Rare earth metal chromites. Szklo i ceram, v. 25, no. 10, 1974, 303-307. (RZhKh 19M, 7/75, no. 7M76). (Translation)

Synthesis, physico-chemical properties and applications of rare-earth chromites are reviewed. These compounds are shown to be promising materials for MHD generators and other purposes.

Strakhov, V. I. and V. K. Novikov. Kinetics of synthesis of yttrium, neodymium and cerium chromites. ZhPKh, no. 12, 1975, 2739-2740.

The title compounds, which are used as electrode materials in MHD converters, were synthesized from mixtures of corresponding rare earths and  $\text{Cr}_2\text{O}_3$ . Reaction kinetics data show that the reactions of  $\text{Y}_2\text{O}_3$  and  $\text{Nd}_2\text{O}_3$  are practically completed within 1 hr at 1400° C and 1000° C, respectively.  $\text{CeO}_2$  reacts completely with  $\text{Cr}_2\text{O}_3$  in 30 min at 1600° C in vacuum. The reaction products are  $\text{YCrO}_3$  and  $\text{NdCrO}_3$  with a perovskite lattice, and  $\text{CeCrO}_3$  with 3.84 Å lattice constant. Activation energy of diffusion reactions is calculated for  $\text{YCrO}_3$  and  $\text{NdCrO}_3$ .

Strakhov, V. I., V. K. Novikov and L. P. Salova. Sintez, termo-mekhanicheskiye i elektricheskiye svoystva ogneuporov iz  $ZrO_2$ , stabilizirovannoy okislami RZE. (Synthesis, thermomechanical and electrical characteristics of  $ZrO_2$  refractories stabilized with rare earths). Leningrad tekhnologicheskiy institut. Deposit at VINITI no. 379-75 Dep, 14 February 1975, 32 p. (RZhKh 19M, 12/75, no. 12M98 Dep.). (Translation)

Efficiency of  $ZrO_2$  stabilization with rare earths is shown. At  $1750^\circ$ , 20 mol %  $CeO_2$ , 12 mol %  $Nd_2O_3$ , 10 mol%  $Sm_2O_3$  or 8 mol %  $Eu_2O_3$  additions are required to fully bind  $ZrO_2$  into a cubic (tetragonal) solid solution. The  $ZrO_2$ - $Nd_2O_3$  solid solution is the most decomposition-resistant during slow cyclic heating and cooling between 20 and  $1200^\circ$ . The effects of  $ZrO_2$  partial destabilization on changes of the most important mechanical characteristics of  $ZrO_2$  refractories are ascertained. A relationship is established between thermal stability of the products and distribution of unstabilized  $ZrO_2$  from decomposition of the cubic (tetragonal) solid solution within a refractory structure. The data on electrical conductivity and conductivity characteristics are given for  $Nd_2O_3$ -,  $CeO_2$ -, and  $Nd_2O_3$ - $CeO_2$ -stabilized  $ZrO_2$  products.

Tikhonov, P. A., A. K. Kuznetsov, E. K. Keler and M. V. Kravchinskaya. Formation stability and electric properties of fluorite-like solid solutions in the  $ZrO_2$ - $CaO$ - $Y_2O_3$  system. NM, no. 4, 1975, 690-694.

Chemical and x-ray phase analysis as well as electrical conductivity measurement data are given for specimens of fluorite-like solid solutions of a  $ZrO_2$ - $CaO$ - $Y_2O_3$  systems. The phase analysis data show that at  $1300^\circ$  C,  $CaO$  is chemically bound into a  $CaZrO_3$  intermediate product which is rapidly converted into a solid solution. Study of decomposition kinetics of the solid solutions at  $1300^\circ$  C indicates that decomposition of the cubic solid solution into a cubic and a tetragonal proceeds by the eutectoid equilibrium mechanism without  $CaZrO_3$  formation. Cubic solid solutions, stable within a  $1200$  to  $1400^\circ$  C range, can be obtained by introducing  $Y_2O_3$  into a  $ZrO_2$ - $CaO$

solid solution.

The  $\log \sigma$  versus absolute T plots of all  $ZrO_2$ - $CaO$ - $Y_2O_3$  compositions studied are exponential in the 1100 to 2000° K range. The observed kink of the plots is interpreted as the result of dissociation of an impurity ion-oxygen vacancy complex. The  $\sigma_{1400^\circ C}$  of all  $ZrO_2$ - $Y_2O_3$ - $CaO$  solid solutions is less than  $4.8 \times 10^{-1} \text{ ohm}^{-1} \times \text{cm}^{-1}$  (the  $\sigma_{1400^\circ C}$  value of the optimum  $Zr_{0.83}Y_{0.17}O_{1.875}$  solid solutions). There are however,  $ZrO_2$ - $Y_2O_3$ - $CaO$  solid solutions with  $\sigma$  very close to that optimum value. These are the solid solutions with a 13 to 18% ( $CaO+YO_{1.5}$ ) content and 0 to 0.5  $[CaO]/[YO_{1.5}] + [CaO]$ . ratios. They are considered as potential materials for heating elements and other high-temperature electrode products.

Zykova, N. M., T. S. Kurakina and A. A. Safonov. Study of the oxide ceramic electrode area affected by electric discharge in a plasma of combustion products. TVT, no. 3, 1975, 630-633.

An experimental study of electric discharge effects on sintered oxide ceramic electrodes is described. Electric discharge was carried out under conditions simulating a discharge in an MHD channel. The materials composed of (in % by wt) 85  $ZrO_2$  - 15  $Y_2O_3$  (I) and 75  $CeO_2$  - 25  $ZrO_2$  (II) were tested as anode or cathode. Open porosity of the type I and II sintered ceramics was 8 to 15%. One of the tested electrodes was an ionic conductor (I) and the other was an electronic conductor (II) with 99 and 5% ionic conductivity component, respectively.

A shifting luminous spot and a crater were observed on the surface of both I and II type cathodes at a breakdown voltage of 100 to 150 v. The erosion mass loss was  $2 \times 10^{-6}$  and  $10^{-5} \text{ cm}^3/\text{C}$  for type I and II cathodes respectively. A darkened area observed on a type I cathode between the crater and current output lead during a high-current discharge formed a conducting channel to the surface and contributed to an increase in conductivity of the discharge-affected area. Thus, the type I cathode behaves like a ceramic with electron-type conductivity.

At a 4 to 5a. discharge current, a luminous spot appears on the anodic surface of both I and II type materials. At  $1800^{\circ}\text{C}$  surface temperature, the anodic spot appears at 1.4 and  $2.8 \text{ a/cm}^2$  on II and I anodes, respectively. The anode under discharge is heated to a higher temperature (to  $1800^{\circ}\text{C}$ ) than the cathode. Electric erosion of the anode was  $2 \times 10^{-6}$  and  $10^{-5} \text{ cm}^3/\text{C}$  for type I and II materials, respectively. Diffusion, which determines cathode darkening, does not develop in the type I anode because of inverted polarity of the electrolytic cell. Thus type I anodes exhibited a higher current of transition to a contracted discharge and a better erosion-resistance than type II.

## SOURCE ABBREVIATIONS

AiT	-	Avtomatika i telemekhanika
APP	-	Acta physica polonica
DAN ArmSSR	-	Akademiya nauk Armyanskoy SSR. Doklady
DAN AzSSR	-	Akademiya nauk Azerbaydzhanskoy SSR. Doklady
DAN BSSR	-	Akademiya nauk Belorusskoy SSR. Doklady
DAN SSSR	-	Akademiya nauk SSSR. Doklady
DAN TadSSR	-	Akademiya nauk Tadzhikskoy SSR. Doklady
DAN UkrSSR	-	Akademiya nauk Ukrainskoy SSR. Dopovidi
DAN UzbSSR	-	Akademiya nauk Uzbekskoy SSR. Doklady
DBAN	-	Bulgarska akademiya na naukite. Doklady
EOM	-	Elektronnaya obrabotka materialov
FAiO	-	Akademiya nauk SSSR. Izvestiya. Fizika atmosfery i okeana
FGIV	-	Fizika goreniya i vzryva
FiKhOM	-	Fizika i khimiya obrabotka materialov
F-KhMM	-	Fiziko-khimicheskaya mekhanika materialov
FMiM	-	Fizika metallov i metallovedeniye
FTP	-	Fizika i tekhnika poluprovodnikov
FTT	-	Fizika tverdogo tela
FZh	-	Fiziologicheskiy zhurnal
GiA	-	Geomagnetizm i aeronomiya
GiK	-	Geodeziya i kartografiya
IAN Arm	-	Akademiya nauk Armyanskoy SSR. Izvestiya. Fizika
IAN Az	-	Akademiya nauk Azerbaydzhanskoy SSR. Izvestiya. Seriya fiziko-tehnicheskikh i matematicheskikh nauk

IAN B	-	Akademiya nauk Belorusskoy SSR. Izvestiya. Seriya fiziko-matematicheskikh nauk
IAN Biol	-	Akademiya nauk SSSR. Izvestiya. Seriya biologicheskaya
IAN Energ	-	Akademiya nauk SSSR. Izvestiya. Energetika i transport
IAN Est	-	Akademiya nauk Estonskoy SSR. Izvestiya. Fizika matematika
IAN Fiz	-	Akademiya nauk SSSR. Izvestiya. Seriya fizicheskaya
IAN Fizika zemli	-	Akademiya nauk SSSR. Izvestiya. Fizika zemli
IAN Kh	-	Akademiya nauk SSSR. Izvestiya. Seriya khimicheskaya
IAN Lat	-	Akademiya nauk Latviyskoy SSR. Izvestiya
IAN Met	-	Akademiya nauk SSSR. Izvestiya. Metally
IAN Mold	-	Akademiya nauk Moldavskoy SSR. Izvestiya. Seriya fiziko-tehnicheskikh i matematicheskikh nauk
IAN SO SSSR	-	Akademiya nauk SSSR. Sibirskoye otdeleniye. Izvestiya
IAN Tadzh	-	Akademiya nauk Tadzhiksoy SSR. Izvestiya. Otdeleniye fiziko-matematicheskikh i geologo-khimicheskikh nauk
IAN TK	-	Akademiya nauk SSSR. Izvestiya. Tekhnicheskaya kibernetika
IAN Turk	-	Akademiya nauk Turkmenskoy SSR. Izvestiya. Seriya fiziko-tehnicheskikh, khimicheskikh, i geologicheskikh nauk
IAN Uzb	-	Akademiya nauk Uzbekskoy SSR. Izvestiya. Seriya fiziko-matematicheskikh nauk
IBAN	-	Bulgarska akademiya na naukite. Fizicheski institut. Izvestiya na fizicheskaya institut s ANEB
I-FZh	-	Inzhenerno-fizicheskiy zhurnal

IiR	-	Izobretatel' i ratsionalizator
ILEI	-	Leningradskiy elektrotekhnicheskiy institut. Izvestiya
IT	-	Izmeritel'naya tekhnika
IVUZ Avia	-	Izvestiya vysshikh uchebnykh zavedeniy. Aviationskaya tekhnika
IVUZ Cher	-	Izvestiya vysshikh uchebnykh zavedeniy. Chernaya metallurgiya
IVUZ Energ	-	Izvestiya vysshikh uchebnykh zavedeniy. Energetika
IVUZ Fiz	-	Izvestiya vysshikh uchebnykh zavedeniy. Fizika
IVUZ Geod	-	Izvestiya vysshikh uchebnykh zavedeniy. Geodeziya i aerofotos"yemka
IVUZ Geol	-	Izvestiya vysshikh uchebnykh zavedeniy. Geologiya i razvedka
IVUZ Gorn	-	Izvestiya vysshikh uchebnykh zavedeniy. Gornyy zhurnal
IVUZ Mash	-	Izvestiya vysshikh uchebnykh zavedeniy. Mashinostroyeniye
IVUZ Priboro	-	Izvestiya vysshikh uchebnykh zavedeniy. Priborostroyeniye
IVUZ Radioelektr	-	Izvestiya vysshikh uchebnykh zavedeniy. Radioelektronika
IVUZ Radiofiz	-	Izvestiya vysshikh uchebnykh zavedeniy. Radiofizika
IVUZ Stroi	-	Izvestiya vysshikh uchebnykh zavedeniy. Stroitel'stvo i arkhitektura
KhVE	-	Khimiya vysokikh energiy
KiK	-	Kinetika i kataliz
KL	-	Knizhnaya letopis'
Kristall	-	Kristallografiya
KSpF	-	Kratkiye soobshcheniya po fizike

LZhS	-	<i>Letopis' zhurnal'nykh statey</i>
MiTOM	-	<i>Metallovedeniye i termicheskaya obrabotka materialov</i>
MP	-	<i>Mekhanika polimerov</i>
MTT	-	<i>Akademiya nauk SSSR. Izvestiya. Mekhanika tverdogo tela</i>
MZhiG	-	<i>Akademiya nauk SSSR. Izvestiya. Mekhanika zhidkosti i gaza</i>
NK	-	<i>Novyye knigi</i>
NM	-	<i>Akademiya nauk SSSR. Izvestiya. Neorganicheskiye materialy</i>
NTO SSSR	-	<i>Nauchno-tehnicheskiye obshchestva SSSR</i>
OiS	-	<i>Optika i spektroskopiya</i>
OMP	-	<i>Optiko-mekhanicheskaya promyshlennost'</i>
Otkr izobr	-	<i>Otkrytiya, izobreteniya, promyshlennyye obraztsy, tovarnyye znaki</i>
PF	-	<i>Postupy fizyki</i>
Phys abs	-	<i>Physics abstracts</i>
PM	-	<i>Prikladnaya mekanika</i>
PMM	-	<i>Prikladnaya matematika i mekanika</i>
PSS	-	<i>Physica status solidi</i>
PSU	..	<i>Pribory i sistemy upravleniya</i>
PTE	-	<i>Pribory i tekhnika eksperimenta</i>
Radiotekh	-	<i>Radiotekhnika</i>
RiE	-	<i>Radiotekhnika i elektronika</i>
RZhAvtom	-	<i>Referativnyy zhurnal. Avtomatika, telemekhanika i vychislitel'naya tekhnika</i>
RZhElektr	-	<i>Referativnyy zhurnal. Elektronika i yeye primeneniye</i>

RZhF	-	Referativnyy zhurnal. Fizika
RZhFoto	-	Referativnyy zhurnal. Fotokinotekhnika
RZhGeod	-	Referativnyy zhurnal. Geodeziya i aeros"-yemka
RZhGeofiz	-	Referativnyy zhurnal. Geofizika
RZhInf	-	Referativnyy zhurnal. Informatics
RZhKh	-	Referativnyy zhurnal. Khimiya
RZhMekh	-	Referativnyy zhurnal. Mekhanika
RZhMetrolog	-	Referativnyy zhurnal. Metrologiya i izmeritel'naya tekhnika
RZhRadiot	-	Referativnyy zhurnal. Radiotekhnika
SovSciRev	-	Soviet science review
TiEKh	-	Teoreticheskaya i eksperimental'naya khimiya
TKiT	-	Tekhnika kino i televideniya
TMF	-	Teoreticheskaya i matematicheskaya fizika
TVT	-	Teplofizika vysokikh temperatur
UFN	-	Uspekhi fizicheskikh nauk
UFZh	-	Ukrainskiy fizicheskiy zhurnal
UMS	-	Ustalost' metallov i splavov
UNF	-	Uspekhi nauchnoy fotografii
VAN	-	Akademiya nauk SSSR. Vestnik
VAN BSSR	-	Akademiya nauk Belorusskoy SSR. Vestnik
VAN KazSSR	-	Akademiya nauk Kazakhskoy SSR. Vestnik
VBU	-	Belorusskiy universitet. Vestnik
VNDKh SSSR	-	VNDKh SSSR. Informatsionnyy byulleten'
VLU	-	Leningradskiy universitet. Vestnik. Fizika, khimiya
VMU	-	Moskovskiy universitet. Vestnik. Seriya fizika, astronomiya

ZhETF	-	Zhurnal eksperimental'noy i teoreticheskoy fiziki
ZhETF P	-	Pis'ma v Zhurnal eksperimental'noy i teoreticheskoy fiziki
ZhFKh	-	Zhurnal fizicheskoy khimii
ZhNiPFIK	-	Zhurnal nauchnoy i prikladnoy fotografii i kinematografii
ZhNKh	-	Zhurnal neorganicheskoy khimii
ZhPK	-	Zhurnal prikladnoy khimii
ZhPMTF	-	Zhurnal prikladnoy mekhaniki i tekhnicheskoy fiziki
ZhPS	-	Zhurnal prikladnoy spektroskopii
ZhTF	-	Zhurnal tekhnicheskoy fiziki
ZhVMMF	-	Zhurnal vychislitel'noy matematiki i matematicheskoy fiziki
ZL	-	Zavodskaya laboratoriya

#### 4. AUTHOR INDEX

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